THE CROONEAN LECTURES ON MUSCULAR MOTION,

By BROWNE LANGRISH M. D. *and* Fellow *of the* ROYAL SOCIETY.

Read before the

ROYAL SOCIETY

In the Year MDCCXLVII.

Being a SUPPLEMENT to the *Philoſophical Tranſactions* for that Year.

> There can be no greater Preſumption in Favour of a Scheme, than that it is ſimple, and of a Piece with the known Syſtem of the Univerſe.
>
> MEAD's *Introd. to his Eſſays on Poiſons*, Edit. 3.

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To the REVEREND

STEPHEN HALES, D.D.

Fellow of the ROYAL SOCIETY,

Theſe THREE LECTURES

ON

MUSCULAR MOTION,

Are humbly dedicated, as a ſmall Acknowledgment for the many and great Advantages received from his moſt curious, learned, and indefatigable Reſearches into Nature; and for the many perſonal and particular Favours which he has been pleaſed to confer on

His Moſt Obedient, and

Moſt Humble Servant,

BROWNE LANGRISH.

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PREFACE.

IN the Year 1733 *I publiſhed an Eſſay on Muſcular Motion, founded on the* Newtonian *Philoſophy of* Attraction *and* Repulſion; *and though the Thoughts were haſtily put together, and the Performance in general, very inaccurate, yet I muſt own I have not met with any Reaſon, ſince that Time, to alter my Sentiments in regard to the Cauſe and Manner of Contraction in the muſcular Fibres.*

I did not think indeed of ingaging myſelf any further in ſolving ſuch abſtruſe Phænomena; *but being deſired by my ever honoured Friend Sir* Hans Sloane *Baronet, to make ſome Experiments which might illuſtrate and confirm the Truth of my* Hypotheſis, *I readily and chearfully complied with his Commands; and afterwards I drew up the following Lectures, which were by Order of the* Preſident *and* Council *read before the* Royal Society, *as the* Croonean Lectures *for the Year* 1747.

purſuant to the Will of the late Lady Sadleir *.

The Foundation of my Scheme is laid upon thoſe Hints which Sir Iſaac Newton *has given us in the* Queries *at the End of his incomparable Book of* Opticks; *together with what Dr.* Pemberton *has ſaid in his very learned Introduction to* Cowper *on the Muſcles. How well it is executed is moſt humbly ſubmitted to my* Superiors. *I do not know that I have advanced any thing inconſiſtent with true Philoſophy; or to any of the known Laws of the animal Oeconomy. I have the Satisfaction to ſee, in the ſecond Volume of the late Dr.* Deſaguliers's *experimental Philoſophy* §, *that he approved of what I had formerly publiſhed, beyond all other Accounts of Muſcular Motion; and I muſt confeſs, that meeting with Countenance from ſo good a Judge gave me great Encouragement to purſue the Enquiry.*

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* *Whoſe firſt Husband was Dr.* Croone, *and at his Requeſt theſe Lectures were founded.*

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THE

THE CROONEAN LECTURES ON MUSCULAR MOTION.

LECTURE I.

SECT. I.

Read at a Meeting of the Royal Society, *on* March 5, 1746-7.

THE external Superficies of every Muſcle, its Origin and Inſertion, the Uſe of its Action in regard to the Animal Oeconomy, from what *Plexus* the Nerve comes, whence the Artery which ſupplies it ariſes, and to what Vein the Blood is carried, are Diſquiſitions very worthy the Knowledge of every *Phyſician* and *Surgeon*; in order to diſcover the true Seats and Cauſes of many Complaints, and to point out the moſt rational Methods of Cure.

II.

But as theſe Reſearches have nothing to do with the immediate Cauſe of Muſcular Motion (the Explication of which ſeems to be the chief Deſign of the Learned *Founder* of theſe Lectures) I ſhall wave all ſuch Enquiries, and proceed directly to inveſtigate by what Means a Muſcle ſo inſtantly and forcibly contracts itſelf, or ſhortens its Length, at the Command of the Will; and this I ſhall endeavour to do by ſuch Rules and Laws as are ſimple, uniform, and intirely agreeable to the known Syſtem of the Univerſe.

III.

In order to the eaſier Illuſtration of this wonderful and important Property in the Fibres, I ſhall give you, 1*ſt*, An analytical View of the component Parts of a Muſcle. 2*dly*, I ſhall ſhew the true Cauſe of Coheſion, Tenſion, and Elaſticity in the animal Fibres. 3*dly*, I ſhall make it appear, that every Fibre conſtituting a Muſcle, is, in its ultimate Diviſion, tubular, and not a Chain of Veſicles or Bladders. And, *laſtly*, I ſhall prove it to be more than probable, that Muſcular Motion proceeds from the *attractive* Quality of the conſtituent Particles of every Fibre being increaſed and ſtrengthened by the Addition of ſome *æthereal Matter* flying out from the Extremities of the Nerves; and that this is inſtantly occaſion'd by the Will, and ceaſes again as ſoon.

IV.

By a chemical *Analyſis* of a Muſcle diſſected from the Buttock of a lean Ox, which weigh'd exactly two Pounds *Averdupois*, I procured,

	Oz.	Dr.	Gr.
1. Lymph — —	xxiiii	xiiii	xv
2. Volatile Salt — —	i	iiii	xxv
3. Oil — —	ii	vi	xx
4. *Caput mortuum* —	ii	ix	v
5. Loſt in Diſtillation, which I preſume was moſtly mere Air	—	xii	xvi
	32	00	00

V.

There being no *Averdupois* Weights in the Shops, leſs than Quarters of Ounces, I order'd ſome to be made of a Drachm, and others of two Drachms. The Drachm weigh'd 27 Grains; ſo that, by caſting up the Grains into Drachms, and the Drachms into Ounces, we have the exact Weight of each of the above conſtituent Principles according to the Weight they were firſt of all weigh'd with.

VI.

It may be proper alſo to obſerve, that the *Apparatus* I made uſe of in this Proceſs, was the ſame which I communicated a Deſcription of to the *Society* ſome time ago, and which is ſince publiſhed in the *Philoſophical Tranſactions* N°. 475; except that the Retort I now uſed was made of Copper, in order that I might remove it from the the Sand-Heat into the actual Fire, without unluting any Part of

the

the *Apparatus*, when no more Matter would ariſe by means of the Sand-Heat.

VII.

By this Method I could increaſe the Fire till the Bottom of the Retort was red-hot, without any Danger of breaking my Recipients; a Contrivance which may be uſeful in many chemical Proceſſes.

VIII.

From the above-mention'd Experiment we have evident Proof of the Proportions and Qualities of the ſeveral Principles, or conſtitutive Parts of the muſcular Fibres; and let no one be ſurpriſed that the watery or phlegmatic Principle abounds ſo much as to be nearly $\frac{13}{16}$ Parts of the whole Maſs, ſince we know that dried Bones, and many other Things as unpromiſing, afford half their Weight of Water.

IX.

That the Particles of Water are endued with a ſtrongly attracting Power, and are highly ſerviceable as a Band of Union in the Formation and Growth of every thing, animate and inanimate, is not only manifeſt from the great Quantity employed in the Growth of Animals and Vegetables, but alſo in our own manual Operations, ſuch as making ſeveral Sorts of Glue, Paſtes, Bricks, and ſuch like, where the watery Particles prove a very durable and powerful *Copula*, and are not to be all of them ſeparated again, even by a very intenſe Fire: Water is to be regenerated from Bricks and Tiles after they have been burnt in the Kiln.

X.

The drieſt Wood, Part of a Mahogony-Table, which had ſtood by the Fire many Years, being raſped and put over the Fire in a Copper Retort, afforded a conſiderable Quantity of Water.

XI.

In ſhort, take away the Water from the moſt ſolid animal and vegetable Bodies, and they immediately become mere Duſt.

XII.

I don't apprehend that this conſiderable Quantity of Water, which is to be procured from ſuch ſolid Subſtances as Bricks, Wood, or even from the muſcular Fibres, remains in diſtinct Drops or Spherules, whilſt it is a Part of ſuch ſolid Subſtances; but I conceive that the *Minima*, or primary ſolid Particles of Water may be attracted by, and actually joined with, the earthy, ſaline, and other component Particles, ſo as to compoſe the ſeveral Degrees of Hardneſs, according to their reſpective Proportions and Qualities; and when theſe ſeveral conſtituent Principles are diſunited again, by the Power of Fire, or by the Length of Time, they riſe up into the Air, or into the Recipient, according to their Diviſibility and Levity; firſt Water, next Salt, then Oil.

XIII.

Nature ſeems to delight in Tranſmutations. Many Kinds of Fluids are eaſily converted into denſe Bodies. We all know how ſoon Water is capable of being turn'd into a very ſolid friable Stone, by the Power of Cold. Mercury alſo is eaſily turn'd into a hard brittle Metal; and both theſe return to their former State of Fluidity by means of Heat. And a Solution of Copper in Spirit of Nitre being pour'd on Oil of Tartar, both Liquids inſtantly become Verdigreaſe in a dry Powder.

XIV.

From what has been ſaid we may obſerve, that Water, or the watery Particles not only make up much the greateſt Part of the muſcular Fibres, but, by mutually attracting, and being attracted by the other component Particles, they greatly contribute towards their Coheſion and Elaſticity; for a fluid Particle will be fixed, and become a Part of a Solid, as ſoon as there is an attractive Force ſufficieent to effect its Coheſion with the other ſolid Parts, though it returns to its former State of Fluidity upon the Analyſis of the compounded Body.

XV.

I would not by this be underſtood as if I deſign'd to exclude the other Principles from their Share which they give to the true Degree of Firmneſs and Elaſticity in the Fibres; the ſaline, ſulphureous, and earthy Parts are all endued with a ſtrongly attracting Power; and when brought into Contact with each other, or with the watry and aereal Particles, they give Firmneſs and Solidity to the Compoſition.

XVI.

Water ſeems to be the *Gluten* by which the other Principles are wrought up. Too much Water in the Compoſition renders the Fibres ſoft and lax; as in Children, and anaſarcous People. Too little Moiſture occaſions a ſtiff, rigid Fibre; as in old Age. There is a certain Degree of Texture and Coheſion neceſſary towards muſcular Motion in its greateſt Strength.

XVII.

I have ſhewn in a former Treatiſe *, that Air is very inſtrumental in fixing and uniting the other Principles which conſtitute an animal Fibre; for in the moſt ſolid Parts of the Body, where the Coheſion is ſtrongeſt, we find great Plenty of Air. That the Air-Particles are capable of being united, and fix'd to ſolid Bodies, and by that means may be eſteemed a Part of their Compoſition, we have many evident Proofs in Dr. *Hales*'s *Analyſis of the Air*; and that thoſe Particles do in their fixed State ſtrongly attract the other component Particles, is evident, it being well known, that the moſt ſtrongly repelling and elaſtic Particles, when in a ſeparate State, are the moſt ſtrongly attracting, when fixed to other Bodies.

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* Modern Theory of Phyſic, *p.* 56.

XVIII.

Now, according to Dr. *Hales*, ſince a much greater Proportion of Air is found in the ſolid than in the fluid Parts of Bodies; may we not with good Reaſon conclude, that it is very inſtrumental, as a Band of Union in thoſe Bodies; thoſe Particles (as Sir *Iſaac Newton* obſerves*) receding from one another with the greateſt repulſive Force, and being moſt difficultly brought together, which upon Contact cohere moſt ſtrongly? And if the Attraction or Coheſion of an unelaſtic Air-Particle be proportionable to its repulſive Force in an elaſtic State, then ſince its elaſtic Force is found to be vaſtly great, ſo muſt that of its Coheſion alſo. Let us add to this, that the Air generated from the fleſhy Fibres, in the Experiment above-mention'd, was not ſeparated without great Violence; for it did not riſe in any Quantity, till the Clouds did, which contain'd and brought over the Salt and Oil: Whence it is evident that the aëreal Particles are firmly fix'd, and conſequently are very inſtrumental in the Union of the other conſtituent Principles.

XIX.

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* Opt. *Qu.* 31.

XIX.

Sir *Iſaac Newton* * thinks, that not only Water and Air are convertible into denſe Bodies, but that even Light may become a Part of groſs Bodies, and that they may receive much of their Activity from the Particles of Light which enter their Compoſition. It is the Opinion alſo of Monſ. *Homberg*, that Light or Fire is a Part of the Compoſition of all Things; though in the Analyſis of Bodies it is always loſt, eſcaping the Skill of the Artiſt, and paſſing through the cloſeſt Veſſels.

XX.

We all know that ſolar Fire, or Light, adds Weight to Lead, Tin, or Regulus of Antimony, when expoſed to the Fire of a burning Glaſs, though they otherwiſe loſe much in Smoak and Steam. But to proceed:

XXI.

Theſe then being then the component Parts of the muſcular Fibres, our next Task is to ſhew the Cauſe of their Tenſion and Elaſticity.

XXII.

That all the muſcular Fibres of the Body are in a State of Tenſion, during Health, is manifeſt from every Inciſion made acroſs them, when the two Segments of the Muſcle ſo divided, retire, one to its Inſertion, and the other to its Origination; that is, every Fibre is always ſtretched out beyond its natural State of Reſt or Quieſcence, ſo that both Ends of it retract a conſiderable Diſtance after being cut aſunder. Now there are two Things which ſeem to be principally concerned in this Affair; *viz.* the Impulſe and Preſſure of the circulating Fluids, always diſtracting the Fibres, and a conſtant *Niſus* or Endeavour in the conſtituent Particles of the Fibres to run cloſer together, when ſo diſtended, by means of their mutual Attraction towards each other.

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* Opt. *Qu*. 30.

XXIII.

The Equilibration which is ever preſerved between the antagoniſt Muſcles, in a healthy State, unleſs when the Will directs it otherwiſe, ariſes from this *Vis Reſtitutionis*; which being ſtronger or weaker according to the Degrees of Tenſion, and the Degrees of Tenſion depending upon the Velocity and Quantity of Fluids circulating through every Fibre; it follows, that as long as the Fluids have the ſame free Acceſs to every voluntary Muſcle, ſo long will the *Æquilibrium* be maintained.

XXIV.

In an Eſſay which I publiſh'd on this Subject of muſcular Motion, in the Year 1733, I endeavoured to prove that every the leaſt Corpuſcle of Matter is endued with an attractive Virtue on one of its Sides, and a repulſive Power on the other, ſomething ſimilar to the Loadſtone; and this I was firſt of all induced to believe, from what Sir *Iſaac Newton* obſerves in his Opticks, *Qu.* 31.

XXV.

When any ſaline Liquor (*ſays he*) is evaporated to a Cuticle, and let cool, the Salt concretes in regular Figures; which argues, that the Particles of the Salt, before they concreted, floated in the Liquor, at equal Diſtances, in Rank and File; and by Conſequence, that they acted upon one another by ſome Power, which at equal Diſtances is equal, at unequal Diſtances is unequal: For, by ſuch a Power, they will range themſelves uniformly, and without it they will float irregularly, and come together as irregularly. And ſince the Particles of *Iceland* Chryſtal act all the ſame Way upon the Rays of Light, for cauſing the unuſual Refraction, may it not be ſuppoſed, that in the Formation of this Chryſtal, the Particles not only ranged themſelves in Rank and File for concreting in regular Figures, but alſo, by ſome kind of polar Virtue, turned their homogeneal Sides the ſame Way?

XXVI.

And again, we are taught by the ſame *Great Man*, that Fire is the moſt ſimple of all known Bodies, and conſequently the moſt immutable; that each Ray of Fire or Light has Sides differently affected, and which have different Properties; and that *Iceland*

Chryſtal is found to attract a Corpuſcle of Fire, if one of its Sides be turned towards the Chryſtal, and repel it, if the other be; for one and the ſame Ray is here refracted ſometimes after the uſual, and ſometimes after the unuſual manner, according to the Poſition which its Sides have to the Chryſtal; and ſince the Chryſtal, by this Diſpoſition or Virtue, does not act upon the Rays, unleſs when one of their Sides of unuſual Refraction looks towards that Coaſt, this argues a Virtue or Diſpoſition in thoſe Sides of the Rays, which anſwers to, and ſympathizes with, that Virtue or Diſpoſition of the Chryſtal, as the Poles of two Magnets anſwer to one another.

XXVII.

We are fully perſuaded, that, in the Chryſtallization of Salts, they could not ſo regularly and conſtantly preſerve their peculiar Shapes, Forms, and Figures, if every Particle of them had not its determinate Poles: For granting that the component Particles of each kind of Salt have a peculiar Shape and Size, different from any other kind of Salt, yet if they had a Power of uniting with each other indifferently, at their Tops, Sides, and Bottoms, one would think they could not always coaleſce into Chryſtals of the ſame regular Figure: But if the conſtituent Particles of every kind of Salt have their determinate Poles, then they cannot poſſibly unite with each other, but when their Poles ſquare with one another, and conſequently they will always fly together, and be joined at ſuch Points, only where their correſponding Poles are; which muſt of courſe conſtantly produce the ſame regular Form and Figure in every Aggregate of ſuch particular ſaline Particles.

XXVIII.

Hence it is, that *Salt Armoniac* ſo elegantly imitates the Branches of a Tree; *Salt of Hartſhorn* a Quiver of Arrows; *Salt of Tin* ſhoots into Lines like little Needles, which ſpread themſelves every Way from a Point, as from a Centre, ſo as to repreſent a Star, *&c.* Now can it be imagined that theſe, or any other kind of Salts, would immutably and perpetually coaleſce into Chryſtals of the ſame regular Figure and Shape from any other Principle?

XXIX.

Since therefore we have ſo much Reaſon to believe that Salts of all kinds, and even the Rays of Light are endued with a polar Virtue, that is, every Corpuſcle attracts on one of its Sides, and repels on the other; and ſince it is a well known Axiom, that *Nature is ever frugal in Principles*, I think it not at all unphiloſophical, or contrary to any of the known Laws of Nature, to believe that every Particle of Matter in the World is endued with an attractive and repulſive Property.

XXX.

Thus then, if the conſtituent Corpuſcles of the muſcular Fibres are formed together according to this Law, if they are all united at particular Points correſponding to their attractive Virtue, it follows, that wherever a muſcular Fibre is ſtretched out to the leaſt Degree of Tenſion, ſome of its Particles will touch each other in fewer Points; whilſt others may poſſibly be diſunited and removed from each other, though perhaps to inconceivable ſmall Diſtances: Hence there will be a conſtant *Niſus* in the ſeparated Particles to get together again; and this *Vis Reſtitutionis* will be ſtronger or weaker, according to the Number of Corpuſcles ſo disjoined, and their attractive Virtue.

XXXI.

If the Power of the circulating Fluids (and I think it cannot be denied) be ſufficient, from the firſt Beginning of the Circulation of the *Fœtus*, and ſo on as long as Life continues, to diſtend the Fibres beyond the Size they would otherwiſe be of, by reaſon of their corpuſcular Attraction; this diſtractile Power muſt always be the Occaſion of ſome Degree of Tenſion in them: And if, upon the Removal of this Tenſion, the component Particles have a Property of running cloſer together, and contracting the Fibres in their Length, by the means abovemention'd, this muſt be the true Cauſe of Elaſticity in the Fibres.

XXXII.

Hence therefore it follows, that ſince the Fibres are always in a State of Diſtraction, by the Quantity and *Momentum* of the circulating Fluids, and as they are ever endeavouring to ſhorten themſelves, by means of their corpuſcular Attraction, their Elaſticity muſt depend upon Tenſion; for the Fibres could have no Power to retract, or abbreviate their Length unleſs they were extended beforehand by ſome certain Force.

XXXIII.

It is not a ſufficient Objection againſt this Scheme to ſay, that if we depend upon what is viſible, we ſhall never ſee the dry ſolid Fibres, or Particles of any ſolid Body, once divided or drawn out of Contact, coaleſce or unite again, or recover the cloſe Contacts they had before; without ſome fluid Medium ſuperadded.

XXXIV.

'Tis true, when a viſible Crack or Flaw happens in any dry, hard, ſolid Body, ſuch as a Steel-Spring, or a dry, rigid, wooden Bow, the Rupture will always continue, by reaſon the ſever'd Particles cannot be brought again into the Sphere of each other's Attraction without the Intervention of ſome Medium; but then it does not follow from hence, that ſuch a Spring or Bow cannot be bent at all without breaking; or that the conſtituent Particles, which muſt neceſſarily be diſplaced by ſuch a diſtending Power, do not fly together again by their attractive Virtue, when removed only to ſuch minute Diſtances.

XXXV.

The *Minima*, or primary Atoms of all Bodies are non-elaſtic, as being perfectly hard, ſolid, and inſeparable; and therefore Elaſticity muſt proceed from the Aggregate, or Compoſition of ſuch Atoms, which, by being capable of changing their Situations, according to the impreſſed Force, and being endued with a powerful attracting Virtue, they inſtantly reſume their former Poſitions, when left to themſelves to obey thoſe Laws which the *Great Creator* hath impreſs'd upon them. As for Inſtance: Whilſt a common Steel Spring, or any ſuch elaſtic Body, is not extended or bent, we preſume every individual Particle of it to be at Reſt; that is, they are all ſituated, in regard to each other, according to their Poles, and embrace one another by their common Principle of Attraction; but no ſooner is ſuch a Spring bent, by ſome impreſſed Force, but many of its Particles on the convex Side, muſt of courſe touch in fewer Points, or perhaps be disjoin'd from each other, though to the moſt minute Diſtances that can poſſibly be; whilſt other Particles, on the concave Side of the Spring, muſt neceſſarily ſlip upon, or be crouded over one another. Hence it will follow, that if thoſe Particles which are ſeparated from each other, or touch one another in fewer Points than uſual, are yet ſo near each other as to be within their Sphere of Attraction, and not at all, or very little alter'd in regard to their Poles, they will conſequently attract each other very ſtrongly, and fly together again, as ſoon as the impreſſed Force is removed; whereas it is no unreaſonable Conjecture to ſuppoſe, that thoſe Particles on the concave Side of the Spring, which are compreſſed, and as it were rumpled over one another, may be ſo much alter'd from their former Poſitions, that their Poles do not now anſwer to each other; and if not, they will repel one another, according to their reſpective

Powers, till they have attain'd their former Situations, or, in other Words, till the Spring has recover'd its former Shape.

XXXVI.

The ſame Principles of Attraction and Repulſion are the Cauſe of Reſtitution or Elaſticity in all other kind of Bodies. When a muſcular Fibre is ſtretched out longer than uſual, it is moſt certain that ſome of its component Particles muſt ſlip upon or by one another, or elſe be removed at exceeding ſmall Diſtances from each other; ſo that if the impreſſed Force be too violent, if the Tenſion be carried ſo far as to disjoin a great Number of the component Particles beyond their Sphere of Attraction, the Fibre will continue to grow weaker and weaker till it breaks: But it is as evident, on the other Side, that when a ſtretched-out Fibre does not break, but retracts itſelf into its former Shape and Dimenſions, upon the Removal of the extending Power, the Particles which were diſplaced return again to their proper Poſitions, merely by the means of their attractive Virtue.

XXXVII.

Now all this being ſo agreeable to thoſe *Laws of Nature* which that divine Man Sir *Iſaac Newton* has diſcover'd to us, I think we have good Reaſon to conclude it to be the true Cauſe of Elaſticity in the animal Fibres.

XXXVIII.

The Elaſticity in the Air indeed, or in Water agitated by Fire, or in all the Exhalations proceeding from the Earth, ariſes from the Principle of Repulſion only; for the Particles of Vapours, Exhalations, and Air, ſtand at a Diſtance from one another, and endeavour to recede as far from one another as the Preſſure of the incumbent Atmoſphere will admit them. No Power yet known is able to compreſs the Air-Particles within the Sphere of their Attraction towards each other, ſo as to deſtroy their elaſtic Property; and yet ſingle primary Particles of Air are continually attracted by other Bodies, and conſolidated with them, till by the Action of Fire, or Fermentation, they are ſeparated again, and reſtored to their repulſive State.

XXXIX.

Hence we may obſerve, that Elaſticity, in different kinds of Things, or in Matter differently modefied, may ariſe from two ſeveral Cauſes, *viz. Attraction* and *Repulſion*; and perhaps, in many Inſtances, from the Influence of both at one and the ſame time.

XL.

Whenever any kind of Matter is actuated by Fire, by Fermentation, or diſſolved by any Menſtruum, ſo as to throw off its Particles in ſubtile Vapour, there will be a conſtant Endeavour in thoſe Particles to recede further from each other; ſo that the more they are confined, or compreſſed, the greater will be their elaſtic Power: Whereas in ſolid Bodies, this Property of Elaſticity proceeds chiefly from Attraction, or a *Niſus* in the component Particles to fly back, or run into cloſe Contacts again, whenever they happen to be ſtretched out, or bent, ſo as to touch each other in fewer Points.

XLI.

From what has been ſaid we may deduce the following *Corollary*, *viz.* That whenever *Elaſticity* proceeds from the Principle of *Repulſion*, as it does in Air, Vapours, *&c.* ſome *Compreſſion* is neceſſary, in order to force the elaſtic Matter into a narrower Compaſs than it would otherwiſe poſſeſs; but when it ariſes from *Attraction*, as in the muſcular Fibres, and all ſolid Bodies, ſome *diſtractile Force* is requiſite to disjoin the component Particles from their uſual Contacts, before it can exert its Power; and perhaps, for want of attending to this Difference, ſo many various Opinions may have ariſen concerning the Cauſe of Elaſticity.

XLII.

In my next LECTURE I ſhall conſider the Shape of the muſcular Fibres, and the Cauſe of muſcular Action.

LECTURE II.

XLIII.

Read March 26. 1747.

IN my former LECTURE I endeavour'd to explore the ſeveral conſtituent Principles of the muſcular Fibres, and to ſhew the true Cauſe of their Coheſion, Tenſion, and Elaſticity. In this, I hope, I ſhall make it appear, 1*ſt*, That every Fibre conſtituting a Muſcle is *tubular*, and of a *cylindrical* Shape, or very nearly ſuch; and not a String, or Chain of Bladders, according to an *Hypotheſis* which has been too long and too generally received. 2*dly*, That the corpuſcular Attraction between the component Particles of the Fibres is ſo far increaſed and ſtrengthen'd by the Influence of the nervous *Æther*, which is always at the Command of the Will, as to purſe up and ſhorten every Fibre in its Length, whereby an Intumeſcence ariſes in the Belly of the Muſcle, though it is contracted in its other Dimenſions, ſo as, in the Whole, to poſſeſs leſs Room.

XLIV.

Being favoured with the Uſe of a moſt excellent Microſcope, I made the following Experiments.

XLV.

1ſt, I divided ſome Fibres as minutely as I poſſibly could, from the Heart of an Ox, from a Part of the Diaphragm, from the intercoſtal Muſcles, and from a Rump of Beef; all which were boiled to ſuch a Degree of Tenderneſs, that we ſeparated ſome Fibres with the Point of a Needle, which were not viſible till placed under the Microſcope, and even then they did not appear bigger than Hairs, though others, which looked like Hairs to the naked Eye, were magnified to the Size of Wheat-Straws. All theſe ſeem'd to be Faſcicles of continued Tubes, as far as we could view them, without any Partitions or Cells.

XLVI.

2*dly*, Upon rending a Muſcle, which was taken from a Knuckle of Veal, and boil'd for four or five Hours, ſeveral of the tranſverſe, as well as longitudinal Fibres appear'd very diſtinctly; which being placed under the Microſcope, and having a ſtrong focal Light caſt upon them by means of a *Florence* Flask fill'd with Water, they ſeem'd to be ſhrunk up, either by being boil'd ſo long, or by being expoſed to the Air, ſo that their Surfaces ſeemed to be unequal and corrugated; which is what Mr. *Leeuwenhoek* * ſays deceived him at firſt, ſo as to make him think theſe Corrugations were ſo many Veſicles or Cells; but he ſoon diſcover'd his Miſtake. In ſome of the Fibres I could plainly diſcern a dark Liſt running in the Centre, from one End to the other; but what it was, I could not diſcover.

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* *Anatom. & Contempl.* p. 43.

XLVII.

3*dly*. Having obſerved the muſcular Fibres in the Leg of a Sea-Crab to divide very eaſily and diſtinctly from one End of the Muſcle to the other; we placed a great many of them under the Microſcope, but could not diſcern any thing like Partitions or Cells.

XLVIII.

In ſhort, Mr. *Leeuwenhoek* * aſſures us, that the minuteſt Fibres that are viſible to the naked Eye appear through a good Microſcope to be inveſted with a Membrane, which includes within it not one ſimple Body, but a Bundle of ſtill finer Fibres, the laſt, or ſmalleſt Order of which he thinks to be ſimple hollow Tubes.

XLIX.

This perhaps is as good Authority as we can have from the Aſſiſtance of Microſcopes; but if we may be allowed to deduce our Arguments from the Analogy which the muſcular Fibres bear to ſome other

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* *Phil. Tranſ.* N°. 367.

Parts of the Body, whoſe Shapes we are well acquainted with, the Reaſonableneſs of this Opinion may appear yet ſtronger.

L.

All Anatomiſts agree, that the muſcular Fibres have their Riſe from the Extremities of the Nerves and Blood-Veſſels; every Fibre being ſupplied by a Branch of a Nerve, and an Artery, and having alſo a Vein ariſing from it.

LI.

That the nervous *Capillamenta* are Cylinders is not denied by any one that I know of; and though the Arteries have been for a great while thought to be conical, yet the ingenious Dr. *John Stephenſon* * Fellow of the *Royal College* of *Phyſicians* at *Edinburgh* hath evidently demonſtrated the whole arterial Syſtem to be Cylinders, frequently divided and ſubdivided, ſtill terminating in Numbers of ſmall Cylinders, the Aggregate of which is always of greater Capacity than the Trunk or larger Cylinder before the Ramification.

LII.

May we not therefore very reaſonably believe, from the Simplicity and Uniformity in all the Operations of Nature, that the muſcular Fibres partake of the ſame Figure with thoſe from whence they have their Riſe; eſpecially when ſuch a Shape (as will appear in the Sequel) is more proper for all the Functions of a Muſcle than any other whatſoever?

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* Medical Eſſays, *Vol.* V.

LIII.

I don't mean by this, that every Fibre of every Muſcle is a perfect and regular Cylinder from one End to the other; many of them may be thicker in their Coats, and larger in their Bores about the Middle than towards each End, ſimilar to the Shape of the Muſcle; but what I think the moſt reaſonable Opinion is, that the ſmalleſt *Fibrillæ* are hollow Tubes not divided into an infinite Number of Cells or Veſicles.

LIV.

The longitudinal, red, fleſhy Fibres ſeem indeed to be contorted and bound about in many Places, with white, ſpiral, and tranſverſe Ramifications of the Nerves; but I can ſee no Reaſon to believe that theſe nervous Filaments divide the longitudinal fleſhy Fibres into ſeveral Apartments or Cells; I rather think that they only dip into the Cavities of the Fibres, in order to convey into them the *æthereal Medium*, which is contained in the Nerves.

LV.

Before the Laws of Nature, and the Animal Oeconomy were ſo well known as they are now, I don't wonder that the veſicular Scheme was thought a reaſonable one, till it came to be examined by ſtrict Rules and Experiments. The common Experiment of raiſing Weights by blowing up Bladders might ſeem, at firſt Sight, a very feaſible Way of explaining muſcular Motion; and without Doubt this firſt of all gave Birth to the veſicular *Hypotheſis*.

LVI.

But the Fallacy of this Experiment was not diſcover'd for want of attending to the Difference between Bladders which have been already blown up, and dried, and ſuch as are recent and ſupple.

LVII.

If a String of dry Bladders, which have been once diſtended as far as they could bear without burſting, and are now again ſqueezed cloſe, and ſtretched out only in their Length, by means of a Weight hung at their Bottom; I ſay, if ſuch a String of Bladders be blown up, it will undoubtedly diſtend their tranſverſe Diameters ſo as to raiſe up the Weight: But in all tender yielding Veſicles, ſuch as the muſcular Fibres moſt certainly are, in their laſt, or ſmalleſt Order, it is well known, that if they were to be inflated with Air, or any ſuch-like Matter, it would them in every Direction alike; they would grow longer as well as wider. Hence it follows, that if the abovemention'd Experiment was to be made with Bladders juſt as they are taken out of animal Bodies, it would not anſwer the Purpoſe, as is evident from blowing up thoſe of *Calves*, *Hogs*, &c.

LVIII.

The muſcular Fibres, it is true, are always in a State of Tenſion, but then this Tenſion is very far from being to their utmoſt Stretch; ſo that, were they to be inflated in the manner above-mention'd, every Muſcle would neceſſarily increaſe in Length as well as Breadth.

LIX.

Another inſuperable Difficulty belonging to the veſicular *Hypotheſis*, is how to blow up a Bladder open at both Ends; which every Veſicle is ſuppoſed to be, by having a free Communication with the Blood-veſſels.

LX.

Having therefore ſo much Reaſon to conclude, that the muſcular Fibres, in their ultimate Diviſions, are not cellular, but tubular, let us proceed to ſhew the Manner and Cauſe of their Contraction.

LXI.

A Muſcle in its Motion very evidently grows leſs in Bulk.

This Propoſition is clearly demonſtrated by that famous Experiment communicated to the *Royal Society*, by Dr. *Goddard*† in the Year 1669, where putting a Man's Arm into a glaſs Cylinder full of Water, the Water always ſunk when the Muſcles of the Arm were contracted, and riſe again to the firſt Standard when they were relaxed. This we think may be look'd upon as an *Experimentum Crucis*; whereas, if every Fibre was a Chain of Bladders, whoſe Contraction in Length aroſe from their Inflation in Breadth, all the World knows there would be a ſenſible Swell of the whole Arm upon muſcular Action.

LXII.

There are ſtill other Difficulties attending the veſicular *Hypotheſis*. If the animal Spirits are ſuppoſed to inflate the Cavities of the muſcular Fibres merely by a propulſive Force, like unto the Steam of boiling Water working in the Engine to raiſe Water by Fire, it ought to be proved from whence ſo ſtrong an Impulſe ſhould ariſe; and alſo how the Nerves, which are the Conduits thro' which this flatulent Matter muſt be convey'd, ſhould lie ſo looſe and unelaſtic; it being evident from all Experience, that if ſuch an elaſtic flatulent Vapour was to fly thro' the whole Length of the Nerves, with an Energy ſufficient to give a Man a Power of lifting up great Weights, the Nerves muſt be ſtretched out in Proportion, and conſequently would be very tenſe and elaſtic.

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† *Vide* Regiſter of the *Royal Society*, Vol. IV. p. 95.

LXIII.

Thoſe who ſuppoſe the Inflation of the Muſcles to ariſe from a fermentative Motion in the Fluids, ought to prove, by a proper Number of Experiments, that there are Juices exiſting in the Body capable of ſuch ſudden and violent Rarefactions or Exploſions, upon mixing with each other; and if this poſſibly could be done, the Diminution of the Bulk of the Muſcles in Action, would overturn all their Scheme.

LXIV.

Hence it is evident that the *veſicular Hypotheſis* ought to be intirely rejected, as being repugnant to the *Laws of Matter*, and to the *Phænomena* of the Muſcles.

LXV.

By undoubted Experiments we are convinced, that the Intumeſcence of a Muſcle, when it acts, ariſes merely from a Change made in its Figure; that is, as it ſhortens in Length the Belly grows thicker, and yet the Bulk in general is diminiſhed.

Let us therefore inquire after the Agents which are capable of producing ſuch ſurpriſing *Phænomena*, and at the ſame time ſhall be conſiſtent with every other Operation in the Animal Oeconomy.

LXVI.

From what has been ſaid it appears, that Contraction, or muſcular Action, does not depend upon any Fluid dilating or diſtending the Fibres; but, on the contrary, they ſhrink up and grow leſs. The inſtantaneous Alternations from Conſtriction to Dilatation, and *vice verſa*, manifeſtly diſcover that muſcular Motion cannot be cauſed by ſuch Juices as the *Blood*, *Lymph*, and ſuch-like; but it muſt be from ſome more ſubtile *æthereal* Matter, which may be mix'd with the Blood in general, and ſecreted from it by the Glands of the Brain.

LXVII.

Let us but carefully conſider the exquiſite *Apparatus* of the Brain, the Quantity of Blood it receives, the infinite Number of its excretory Ducts, and the great Diviſibility and Subtilty of Matter, and we ſhall find great Reaſon to conclude that there is a moſt ſubtil, æthereal, volatile Fluid, of great Force and Elaſticity, perpetually ſecreted from the Blood, by the Glands of the Brain, and continually flying into the Nerves, for the Uſes of muſcular Motion, and many other great Purpoſes of the Animal Oeconomy.

LXVIII.

The delicate Texture of the Nerves, as well as that of the Brain, implies that the Fluid they convey to the Muſcles muſt be exquiſitely fine. Indeed when a Nerve is wounded, there flows from it a ſweet, ſoft, clammy, balſamic Juice, which no doubt is carried, at all other times, by the evaneſcent Nerves to their ultimate Diviſions, in order to nouriſh and preſerve the moſt minute *Fibrillæ*, and all their Expanſions; and this may properly be called the *Succus nutritius* of the Nerves. But I cannot conceive that this viſible Juice has any thing to do with the immediate Cauſe of voluntary Motion; for ſo viſcous a Matter could never admit of ſuch ſudden Viciſſitudes, as are in muſcular Action, if it was capable of performing it in other Reſpects.

LXIX.

There are Abundance of Conſiderations which evince the Exiſtence of ſome ſubtil Spirit in the Nerves, much finer than to be the Object of our Senſes. We have no Proof, either from Experiment or Reaſon, of any other inſtrumental or phyſical Cauſe of Senſe or Motion, but this *animal Æther* which is elaborated from the Blood.

LXX.

The learned Dr. *Mead* * thinks no Regard ought to be had to the immechanical Notions of thoſe Authors, who imagine that there is no ſuch thing as a nervous Fluid in an animal Body; and that muſcular Motion and Senſation are performed only by the Vibrations of the Fibres of the Nerves, without the Intervention of any ſpirituous Fluid.

LXXI.

The ſurpriſing Diſcoveries which have been made of late Years, by a Variety of Experiments upon Electricity, do in ſome meaſure give us an Idea of the great Subtilty and Velocity of the nervous Fluid. I have been informed by the ingenious Mr. *Watſon*, a worthy Member of this *Society*, that the Swiftneſs of the electrical *Effluvia* is prodigious; that one Stroke of his Hand down the Tube, when well electrified, was felt as ſoon as his Hand could be at the Bottom of the Tube, through five Men ſtanding upon electrical Cakes, and communicating with each other by a Cane, Sword, or any other Non-electric.

LXXII.

Hence it follows, that if a Tube could be always excited, and was always to be applied to the End of a proper Cord or String; the electric Matter, which is excited by Friction between the Hand and Tube, would ever be ready to exert its attractive Influence on Leaf-Gold, and ſuch-like Things, when placed within a due Diſtance of the End of the String; and perhaps this may be very ſimilar to the Motion and Action of the nervous *Æther*.

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* Introduction to his Eſſays on Poiſons, *Edit.* 3.

LXIII.

Thus much being premiſed, and it being taken for granted, that we have an *æthereal Medium* in the Brain, Spinal Marrow, and all the *Capillamenta* of the Nerves, ever ready to be convey'd into the muſcular Fibres, by the Power of the Will, and which *Medium* conſiſting of the moſt refined Matter in Nature; it follows, that the Motion of this nervous *Æther* may be as quick as Lightning, and alſo its attractive Power muſt be exceeding ſtrong, by virtue of its vaſt Degree of Subtilty; as is evident from what Sir *Iſaac Newton* * has calculated concerning the Rays of Light.

LXXIV.

From theſe Obſervations therefore, and from what has been ſaid above concerning the Coheſion and Elaſticity of the animal Fibres, I think we have great Reaſon to conclude, that muſcular Motion does proceed from the Influence which the nervous *Æther* has upon the component Particles of the muſcular Fibres themſelves, by inſtantly increaſing their attractive Virtue towards each, ſo as to make them run cloſer together, or, as it were, up into Heaps, as long as ſuch an additional attractive *Medium* is in the Fibres.

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* Opt. *Qu.* 23, 24.

LXXV.

If we look back and conſider the Nature of the *Vis Reſtitutionis*, or Elaſticity in the muſcular Fibres, we ſhall find, that the Cauſe of that Property only wants to be increaſed, in order to overcome the diſtractile Force of the circulating Fluids, and the Reſiſtance of the antagoniſt Muſcles: Whence it follows, that if ſuch a Power was to be increaſed in one Set of Muſcles, and not in their Antagoniſts, thoſe Muſcles, whoſe elaſtic or retracting Power was increaſed, would be abbreviated in their Length, whilſt the others would be extended and lengthen'd.

LXXVI.

When any Muſcle is freed from the Power of its Antagoniſt, by a Wound, *&c.* it immediately contracts, and is not to be extended again by the Power of the Will. Whence it has been ſaid, that Contraction is the proper State of the Muſcles, and to which they always tend: But if we narrowly inſpect into this Affair, we ſhall find, that, when a Muſcle is contracted in this manner, it is no further ſo than the elaſtic reſtitutive Property in the Fibres is concerned. We do not find that ſuch a Muſcle is indurated, or its Belly ſwoln like unto what it is in voluntary Action; for here being no Influx of the nervous *Æther* to increaſe the corpuſcular Attraction, the Muſcle is ſhortened only by the inherent mutual Attraction between the conſtituent Particles of its Fibres, without any Matter being ſuperadded. This kind of Contraction therefore is evidently the State to which the elaſtic Fibres, tend by a continual *Conatus* in the component Particles to accede towards each other without the Aſſiſtance of the nervous *Æther*; ſo that this natural *Vis motrix* in the muſculous Fibres is no more than what we mean by their Elaſticity, or reſtitutive Property: It ſeems however to be demonſtrated from hence, that muſcular Action, and Elaſticity in the Fibres, proceed from the ſame Cauſe in different Degrees; *viz.* from corpuſcular Attraction.

LXXVII.

Let us now endeavour to corroborate theſe Arguments by ſome ſuitable Obſervations.

LXXVIII.

1*ſt.* From what has been ſaid we may conceive more readily, than we know how to expreſs, that the Will has a Power to direct the *æthereal Medium* contain'd in the Nerves, to any of the voluntary Muſcles, with ſuch a Degree of Celerity as it pleaſes; and to ſtop the Influx as ſuddenly.

LXXIX.

2*dly.* It is evident that the Coats, or carnous Subſtance of every Fibre, muſt neceſſarily increaſe in its

Thickneſs, when it abates in its Length; and what Power can produce this Effect, but ſuch a one as increaſes the mutual Attraction between the conſtituent Particles?

LXXX.

3*dly*. Hence appears the Reaſon, why the Belly of a Muſcle ſwells during its Contraction, notwithſtanding its Dimenſion in general is diminiſh'd; for as the component Particles of each Fibre are more looſely join'd together about the Middle than towards its Extremities, which are generally tendinous, it is natural to ſuppoſe that the chief Action is between them; that is, when a Fibre grows ſhorter, ſuch of its Particles which are moſt at Liberty run nearer together, and as the Motion of all Bodies is ever in proportion to the Impulſe they receive, and the Reſiſtance they meet with, ſo when the conſtituent Particles of the muſcular Fibres are drawn into a ſhorter Compaſs, by the means above-mention'd, the Middle of the Fibres muſt ſwell either inwardly or outwardly, or both, according to the Reſiſtances they meet with.

LXXXI.

And *laſtly*, Since the Coats of the muſcular Fibres do moſt certainly grow thicker as they contract in their Length, and yet the external Surface of the Muſcle in general is diminiſhed; it manifeſtly follows that their Cavities muſt grow leſs, and their contain'd Fluids muſt be preſſed out, in proportion to the Contraction of the Muſcle.

LXXXII.

This appears upon Blood-letting, when ſqueezing any thing hard in the Hand will make the Blood fly out with a greater Velocity, and thereby form a larger *Parabola.*

LXXXIII.

This alſo accounts clearly for the Induration and Paleneſs of a Muſcle during its Action.

LXXXIV.

And again, it follows hence, that in the Action of the Muſcles there is an alternate *Diaſtole* and *Syſtole* perfectly analogous to the Action of the Heart, which greatly contributes towards puſhing on the Blood in the Veins.

LXXXV.

The Muſcles being contracted merely by the Influence of the nervous *Æther,* and the Influx of the *Æther* being ſtopt by withdrawing the *Impetus* given to it by the Power of the Will; the Reaſon and Manner of their Relaxation will eaſily appear. For ſince the nervous Fluid is extremely ſubtile, that Portion of it which is thrown into the muſcular Fibres, acts but for a Moment, or the leaſt

Space of Time, ſo quick is it in its Motions, and ſo penetrating in its Nature; and no ſooner is the Vigour of the Attraction over, but the Tenſion of the Antagoniſt Muſcles, and the Impulſe of the Blood will extend them again.

LXXXVI.

Whoever duly conſiders the well known Effects of magnetical and electrical *Effluvia* will be at no Loſs to conceive the inſtantaneous Influence which the nervous *Æther* has upon the muſcular Fibres.

LXXXVII.

It muſt be confeſs'd indeed, that theſe *Intima Naturæ*, or ſecret Operations in the Animal Oeconomy are all skreen'd from our Knowledge, the Agents being too ſubtil ever to become the Objects of our Senſes, though ever ſo well aſſiſted; ſo that we can only form our Schemes, and deduce our Arguments from ſuch collateral Proofs, or from ſuch *Data* as we are pretty ſure are true. As for Inſtance; the Influence which the *Soul* has upon the *æthereal Medium* in the Nerves muſt be by Impulſe; for though our finite Capacities are not able to comprehend the Nature of immaterial Impulſe; yet nothing is more certain than that the moſt ſubtil Matter in the Univerſe cannot be moved without ſome impreſſed Force.

LXXXVIII.

That the Will does exert itſelf after this manner, is in a good meaſure proved by Dr. *Stuart*'s * Experiment upon a Frog, where a proper Impulſe being given to the *Medulla ſpinalis* did excite Motion in the voluntary Muſcles, though the Head was ſever'd from the Body.

LXXXIX.

Hence alſo it appears, that the Nerves are always replete with a ſubtil Fluid capable of contracting the Muſcles, or otherwiſe ſuch an Impulſe on the Beginning of the Nerves, could not have excited Motion after the Head was cut off.

XC.

And again, common Experience aſſures us, that tho' the Nerves are always replete with an *æthereal Medium*, yet this *Medium*, in a State of Health, never flies out at their Extremities, into the muſcular Fibres, without ſome Impulſe by the Direction of the Will: Whenever it happens to do ſo, Convulſions and Cramps are the natural Conſequences.

XCI.

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* Lectures on Muſcular Motion.

XCI.

It may perhaps ſeem ſtrange to ſome, that I have not all this while taken any Notice of the Blood, as an Agent in muſcular Motion; ſince it has ever been reckoned ſome way neceſſary towards it. But notwithſtanding this Opinion has been ſo long and ſo generally received, yet if our Scheme be the true one, it evidently appears the Blood hath nothing to do with the immediate Contraction of the Muſcles.

XCII.

From the cloſe Connection of the nervous *Capillamenta* in all or moſt of their Ramifications, to thoſe of the Arteries, it ſeems as if the *Diaſtole* and *Syſtole* of the arterial Syſtem was ſome how uſeful to them. Perhaps it may aſſiſt in puſhing on the *Succus nutritius*, or that clammy balſamic Juice which is in the Nerves, towards their Extremities; but I cannot conceive that the Blood itſelf is in any way aſſiſting towards muſcular Motion, except it be by keeping the Fibres warm, ſupple, diſtended, and every way ready for the Influx of the nervous *Æther*.

XCIII.

I have tied up and cut aſunder both the *Carotid* and both the *Crural* Arteries of the ſame Dog, without deſtroying the Motion of one Muſcle. Nothing leſs than laying a Ligature on the *Aorta deſcendens* will deſtroy the Motion of the hinder Parts; and poſſibly this may happen from the great Diſtenſion of the *Aorta* above the Ligature, preſſing upon the Nerves which go to the lower Parts.

XCIV.

It is certain indeed, when all the Blood is intercepted the Fibres will ſoon collapſe, and grow flaccid, and muſcular Motion will ceaſe, merely for Want of the Warmth, Suppleneſs, and Diſtenſion which the Muſcles receive from the Blood. But what I think moſt reaſonable is, that the Blood is no Way concerned as an efficient Cauſe in purſing up and contracting the Fibres s it rather by its Motion through the Muſcles, acts as an Antagoniſt to their Contraction, by extending and diſtending them; for the Blood, by the *Diaſtole* and *Syſtole* of the Arteries, is continually urging on its Paſſage through the Muſcles.

XCV.

Thus I have endeavour'd to deduce and illuſtrate the Cauſe of muſcular Motion from true Principles, by purſuing only thoſe *Laws of Nature*, which our great Philoſopher Sir *Iſaac Newton* has in ſo ſurpriſing a manner diſcover'd to us. But I am far from thinking this a complete Account; I know it requires more Experiments, and better Reaſonings than I am Maſter of, to explain it as it ought; and even after all, there are, and ever will be, ſome Things above the Reach of our Capacities to demonſtrate,

ſtrate, any otherwiſe than by their Effects, or ſecond Cauſes: Such are, the Nature of an immaterial Impulſe; the real Exiſtence of ſo ſubtil a Fluid as is attributed to the Nerves; and the true Cauſes of Attraction and Repulſion.

XCVI.

That the Supreme Being hath implanted an immaterial Spirit in every living Creature, for the Purpoſes of Senſation and voluntary Motion, I think cannot be denied by any one in his Senſes: But perhaps it may not become us to be too ſollicitous about the *Modus* of Action betwixt the *Soul* and *Matter*; theſe Things being above the Reach of human Reaſon. It is ſufficient for our Purpoſe, that we know the Will has a Power of determining the nervous *Æther* immediately and directly to every individual voluntary Muſcle.

XCVII.

The Exiſtence or Non-Exiſtence of the nervous Fluid, commonly called the animal Spirits, has been a Controverſy of long ſtanding. The firſt Searchers into the Structure of the human Body ſoon found that muſcular Motion depended upon the Nerves, or ſomething within them; and this has conſtantly been aſſerted, and admitted as a known Truth. The Advocates for the Exiſtence of animal Spirits have generally ſuppoſed that voluntary Motion was performed by a ſudden Inflation of the Muſcles, either by the Power of the nervous Fluid itſelf, or by an inſtantaneous Ferment with ſome other Fluid; and I am apt to believe, that this Doctrine proving inconſiſtent with many Things relating to the Animal Oeconomy, and contrary to ſome known Experiments, might give Riſe to the vibrating Scheme, where the Exiſtence of the animal Spirits is denied, and where it is ſuppoſed that both Senſation and muſcular Motion may be performed merely by the Elaſticity of the Nerves, and Contractions firſt of all begun in the Brain, and ſo communicated to the fleſhy Fibres: But this is ſo immechanical a Notion as not to deſerve an Anſwer; it being impoſſible for a vibrating Motion in one Cord or String, were it ever ſo elaſtic, to cauſe a Contraction in another, without the Intervention of ſome Fluid.

XCVIII.

I ſhall conclude this Lecture therefore with obſerving, that the Exiſtence of an *æthereal Medium* in the Nerves is paſt all manner of Doubt; it being otherwiſe contrary to the known Laws of Nature for the Nerves to be the Cauſe of muſcular Motion if they were ſolid, or did not admit the moſt ſubtil Fluid, ſecreted by the Glands of the Brain, to paſs through them.

XCIX.

And ſince it is known from Experiment, that the Muſcles grow leſs in Action, and, conſequently, the conſtituent Particles of every Fibre muſt run nearer together before ſuch a *Phænomenon* can happen; we think it very manifeſt that this Property of Conſtriction ariſes from the Principle of corpuſcular Attraction being increaſed and ſtrengthened by the Influence of the nervous *Æther*; a Principle, which, from the endleſs Diviſibility and Subtilty of Matter, we may never be able to comprehend, though we know it to exiſt in Nature from innumerable Obſervations and Experiments.

The End of the Second Lecture.

LECTURE III.

XCV.

Read April 9. 1747. IN Confirmation of the Truth of what has been ſaid in the two preceding Lectures, and for a further Illuſtration of this Subject of muſcular Motion, I beg Leave to offer ſome Thoughts concerning the Cauſe and Manner of Action in the involuntary Muſcles; and after that I ſhall relate ſome Experiments, which I have made in order to illuſtrate our Theory in general, as far as the Nature of the Subject will admit.

XCVI.

When any Muſcle, voluntary or involuntary, is fully contracted, that is, when its component Particles are drawn into the cloſeſt Contacts they are capable of, by the Influence of the *æthereal Medium* in the Nerves, it is evident, from all the Laws of Matter, that they would not recede from each other again without ſome impreſſed Force. Now in all the voluntary Muſcles we very well know, that when one Set of them are contracted, their Antagoniſts are lengthen'd, and *vice verſa*; ſo that the *Vis Reſtitutionis* in all the ſtretched-out Fibres, and the

Momentum of the Fluids to enter again into the contracted Muſcles, will inſtantly dilate and diſtract them, when the Impulſe of the Will ceaſes, till an exact Equilibration is reſtored.

XCVII.

This being the plain Matter of Fact in regard to the voluntary Muſcles; let us now endeavour to find out the Mechaniſm belonging to the involuntary ones, and more particularly of that very curious one the Heart.

XCVIII.

Dr. *Hoadly*, in his *Lectures on Reſpiration*, has manifeſtly ſhewn that the external Ranges of the intercoſtal Muſcles appear to have all the characteriſtic Marks of antagoniſt Muſcles. If you take three Ribs together, *ſays he*, and obſerve the different Ranges of the Fibres in the two intercoſtal Muſcles, which lie on each Side the middlemoſt of theſe Ribs; you will ſee, at firſt Sight, that the internal Range in the lower Muſcle, counter-acts directly the external Range in the upper Muſcle.

XCIX.

The Action of the *Diaphragm* is alſo counterbalanc'd by the abdominal Muſcles, and Contents of the *Abdomen*; which ſqueeze it up, in a convex Form, into the Cavity of the *Thorax*, upon every Expiration.

C.

As to the *Sphincter* Muſcles, they ſeem to be always in the ſame natural contractile State; and whenever they are ſtretched out, by ſome ſuperior Power, they recover their uſual Dimenſions merely by their reſtitutive or elaſtic Property. The ſame may be ſaid of the *Stomach*, *Uterus*, *Veſica*, which contract by the ſame means, into a narrower Capacity, as ſoon as their Contents are diſcharged.

CI.

I ſhall confine my Thoughts therefore to the Action of the Heart only, as being the moſt perfect involuntary Muſcle.

CII.

The Heart is a *Viſcus* which has given the *Literati* a great deal of Trouble to find out its real Mechaniſm, and the true Cauſe of its regular Alternations of Contraction and Dilatation. I have oftentimes laid open the Breaſt of a Dog, and kept his Lungs playing with a Pair of Bellows, in order to obſerve how regularly and alternately the *Syſtole* and *Diaſtole*, both of the Heart and its Auricles, followed each other; that is, when the Ventricles were contracted, the Auricles were dilated, and *vice verſa*; ſo that the Auricles ſeem, in ſome meaſure, to act as Antagoniſts to the Ventricles, and the refluent Blood may be of the ſame Service to the Auricles.

ricles. But there being ſo much Diſparity between the contractile Strength of the Ventricles and that of the Auricles, there muſt neceſſarily be ſome other Cauſe, which, when the Heart is fully contracted, makes it unbend again, or ceaſe to contract; by which means the Auricles, though ſo very weak in compariſon of the Ventricles, have Power enough to throw in Blood, and thereby to diſtend the Ventricles to a certain Degree, before they are capable of acting again.

CIII.

If we might be allowed to make an Eſtimate of the Difference between the contractile Strength of the Heart and its Auricles, from the Difference of their Bulk, or Quantity of Fibres, we ſhould find it to be about *nine* to *one*; as I have obſerved, by weighing the Hearts of ſeveral Animals, and their Auricles ſeparately.

CIV.

Hence it does not ſeem reaſonable to think, that the weak Efforts of the Auricles would be ſufficient to cauſe the *Diaſtole* of the Heart, without ſome other Aſſiſtant.

CV.

One great Uſe of the Auricles is, to receive a Quantity of Blood, during the *Syſtole* of the Heart, ſufficient to fill the Ventricles again at their *Diaſtole*.

ſtole. The ſame may be ſaid, in ſome meaſure, of the Veins neareſt the Heart, which may be plainly ſeen to dilate during the Contraction of the Auricles; ſo that the Heart, Auricles, and Veins, have all their *Syſtoles* and *Diaſtoles* in ſubordinate Degrees.

CVI.

Without ſuch Receptacles as theſe it would be impoſſible for the Ventricles of the Heart to be fill'd from the Veins ſo ſuddenly as they are; for though the *Areas* of the tranſverſe Sections of the Veins are much larger than thoſe of the Arteries, yet we find, by Dr. *Hales*'s *Hæmaſtatical Experiments*, that the Velocity of the Blood in the Arteries is above *ſix* to *one* to that in the Veins: But ſince the Auricles keep receiving the Blood whilſt the Heart is in its *Syſtole* (the Veins doing the ſame by the Auricles) a due Quantity of Blood is always ready to be thrown into the Heart, by the Time it is fit to receive it; for the *Diaſtole* takes up two Thirds of the Space of Time between each Pulſe.

CVII.

Here then we may obſerve that the *Momentum* of the refluent Blood acts upon, and diſtends the Veins neareſt the Heart, whilſt the Auricles are contracted; that it alſo dilates the Auricles, whilſt the Heart is in Action; and that the Heart is in its *Diaſtole*, whilſt the Auricles are in their *Syſtole*.

But the great Difficulty in accounting for the *Diaſtole* of the Heart, is from the Diſproportion between its contractile Power, and that of the Auricles; it being plain, from what has been ſaid above, that the *Momentum* of the Blood in the Veins is ſtopt by the Contraction of the Auricles, ſo that the Ventricles of the Heart can receive no other Impulſe from the Blood at that time, than what is derived from the Contraction of the Auricles.

CVIII.

Hence therefore it follows, that if the *Syſtole* was the natural State of the Heart, and to which it always tended with its full contractive Power, the Impulſe of the Blood, from the Contraction of the Auricles, could never be able to dilate it.

CIX.

Dr. *Lower* makes the *Syſtole* the natural State or Action of the Heart, and the *Diaſtole* the violent one: *Boerhaave*, on the contrary, makes the *Syſtole* the violent, and the *Diaſtole* the natural State. But perhaps neither of theſe Opinions may be right, in the ſtricteſt Senſe; for if we look back we ſhall find, that if the Fibres were not tenſe they could not be elaſtic; and if ſome Violence was not put upon them, by the Impulſe of the circulating Fluids, they would not be tenſe: Hence it appears, that Elaſticity proceeds from a State of Violence.

CX.

And again; When a Muſcle is freed from the Power of its Antagoniſt, and is thereby left at full Liberty to contract, as it always will by its elaſtic, reſtitutive Property only, it does ſo no further than in Obedience to the common Power of Attraction between its component Particles; but in all other muſcular Action, when this attractive Power is greatly increaſed by the Influx of the nervous *Æther*, the Conſtriction is carried much further, and the Muſcle is more fully contracted than it ever is in the other State: Hence it follows, that Contraction, in its fulleſt Degree, is not the natural State of a Muſcle.

CXI.

And further; When the conſtituent Particles of the Fibres are drawn into their cloſeſt Contacts, by the Influx of the nervous *Æther*, it requires ſome Force, in a contrary Direction, to elongate the Fibres again; ſo that Extenſion, or Dilatation is alſo a State of Violence.

CXII.

From the Whole then it appears, that neither the *Syſtole* nor *Diaſtole*, in a full Degree, is the natural State of the Heart; and this we ſhall ſhew more plainly hereafter by inſpecting the Hearts of Animals after being bled to Death. But to proceed:

CXIII.

From what has been ſaid above, it ſeems reaſonable to conclude, that if Contraction, in its fulleſt Degree, was the natural State of Reſt or Quieſcence in the Heart; the *Momentum* of the Blood from the Contraction of the Auricles, could not be a ſufficient Counterpoiſe. And ſince ſo many fruitleſs Attempts have been made to account for the *Diaſtole* of the Heart; from the *Impetus* of the Blood in the Veins, and from the Preſſure of the Atmoſphere, *&c.* give me Leave to propoſe the following *Queries.*

CXIV.

1ſt. May not the Heart be a compound Muſcle; that is, may it not have its Antagoniſt within itſelf? Or, in other Words, are not ſome of its Fibres ſo ranged, that whilſt one Set of them is contracted and ſhorten'd, others may be ſtretched out; analogous to the Action of the intercoſtal Muſcles, or any other Muſcles with their Antagoniſts?

CXV.

2dly. Is the nervous *Æther* tranſmitted from the Brain to the Heart in a pulſatory Manner, at equal Diſtances of Time; or may it be ſuppoſed to move uniformly through the Nerves, and ſome Interruption is given to its Influx into the muſcular Fibres, when the Heart is in its *Syſtole?*

CXVII.

3dly. Does not the *Diaſtole* of the Heart depend upon an Abatement of the Tenſion in the contracted Fibres; a Motion of Reſtitution in ſuch as are over ſtretched; and the Influx of the Blood conjunctly?

CXVIII.

Without ſome ſuch Mechaniſm as this, no Power that we know of, belonging to the animal Oeconomy, would be able to cauſe the *Diaſtole* of the Heart: But if ſuch a Structure, as is above-mention'd, could be proved, no more Difficulty would attend the Explication of it than that of the voluntary Muſcles.

CXIX.

In diſſecting the Heart we find a great many different Orders or Series of Fibres, variouſly contorted, and running in contrary Directions; ſo that, for ought we know, it may be an *Epitome* of muſcular Conſtruction in general.

CXX.

We may here obſerve what Care *Nature* has taken to prevent too great a Dilatation in the *Diaſtole* of the Ventricles, the right one eſpecially, as being the weakeſt, by forming the *Papillæ*, or *Columnæ*, which run from the *Septum*, or middle Partition, to its oppoſite Sides; whereby they act as ſo many Braces in the *Diaſtole*, and when they contract, they alſo aſſiſt in the *Syſtole*. And perhaps it may not be the moſt improbable Conjecture to think; that as much Care may have been taken in providing a ſufficient Number of Fibres, or little Muſcles, which may be ſo formed as to act in the *Diaſtole*, as Antagoniſts to thoſe which occaſion the *Syſtole*.

CXXI.

The Hearts of Frogs, Vipers, Eels, *&c.* ſeem to evince the Reaſonableneſs of this Conjecture, by continuing their *Syſtoles* and *Diaſtoles* after they are taken out of the Body; when there is no refluent Blood to dilate the Ventricles, and, conſequently, if there were no Fibres upon the Stretch, when the Heart is contracted, which, by their Elaſticity, or reſtitutive Power, did pull back, or elongate ſuch as were contracted, there could not poſſibly be any *Diaſtole* in ſuch Circumſtances.

CXXII.

We are aſſured by Mr. *Boyle*, in his *Phyſico-Mechanical Experiments*, that the Heart of an Eel hath continued to beat an Hour, in an exhauſted Receiver; after which, finding its Motion very languid, and almoſt ceaſed, by breathing a little upon that Part of the Glaſs where the Heart was, it quickly regain'd Motion; and an Hour after that, finding it almoſt quite gone, he was able to renew it, by the Application of a little more Warmth.

CXXIII.

The ſame *illuſtrious Author* further aſſures us, that he has ſometimes cut the Heart of a Flounder tranſverſely, into two Parts; and freeing each from the Blood it contain'd, he obſerved, for a conſiderable Time, that both of them together continued their former Contraction and Relaxation. And once, thus cutting one into ſeveral Pieces, he found, to his Surprize, that they not only moved as before, but that even the Whole, thus ſeparated, long preſerved the ſame Succeſſion of Motion, as appeared therein whilſt coherent.

CXXIV.

Now can the *Diaſtole* of the Heart, in theſe Experiments, be accounted for upon any other Principles than thoſe we have laid down? Here was no Impulſe from the refluent Blood to dilate the Auricles, or to diſtend the Ventricles. The Preſſure of the Atmoſphere was alſo quite taken away in the firſt Experiment, and could not poſſibly be of any Service in the laſt; and yet the *Diaſtole* continued.

CXXV.

Can the ſame Fibres which are contracted, have it in their own Power to fly out again to their uſual Lengths? If this cannot be, what Power is there in a Heart, taken out of the Body, to unbend itſelf, or to dilate its Ventricles, after they are once contracted, unleſs we ſuppoſe ſome of its Fibres to act as Antagoniſts to others?

CXXVI.

We have good Reaſon therefore to believe that ſome Fibres of the Heart are always ſtretched out beyond their natural Tone, when others are contracted; ſo that, by their elaſtic, reſtitutive Property, they do act as Antagoniſts in a certain Degree.

CXXVII.

In regard to the *Syſtole*, in ſuch Hearts as are taken out of the Body, and cut into ſeveral Pieces, we conceive, that as long as Warmth and Moiſture remain, ſo long may the *æthereal Matter* in the Nerves, continue to fly into the Fibres, and contract them; and when it ceaſes, more Warmth, or a gentle Impulſe (even with the Point of a Needle only) will revive the Motion.

CXXVIII.

Hence we may, in ſome meaſure, diſcover the amazing Subtilty of the nervous *Æther*; when ſuch very ſmall Sections of the Nerves, as in the above-mention'd Experiment upon the Heart of a Flounder, ſhould contain Matter ſufficient for ſo many Contractions.

CXXIX.

Let us now return to our *ſecond Query*, and examine whether the nervous *Æther* is tranſmitted from the Brain to the Heart, in a pulſatory Manner, at equal Diſtances of Time; or whether ſome Interruption is only given to its Influx into the muſcular Fibres, when the Heart is in its *Syſtole*.

CXXX.

In order to underſtand this, we muſt look back and conſider, that, according to our Theory, if the *æthereal Medium* in the Nerves was perpetually flying into the muſcular Fibres of the Heart, it would be conſtantly contracted, notwithſtanding the *Momentum* of the Blood, the Contraction of the Auricles, or the *Vis Reſtitutionis* in the ſtretched-out Fibres. Hence then it is evident, that the alternate Contractions and Dilatations of the Heart proceed from an alternate Influence of the nervous *Æther*; but how this Alternation happens, when the Nerves which ſupply the Heart are not, in the leaſt, under the Direction of the Will, is the Difficulty we labour under.

CXXXI.

In all the Nerves which ſupply the voluntary Muſcles, it is certain there are Reſtrictions in ſome Parts of them which the *æthereal* Matter is not able to dilate without an additional Impulſe from the

Will; or otherwiſe Cramps and Convulſions would perpetually happen. But in thoſe which ſupply the Heart, the Motion of the *Æther* through them cannot have any Aſſiſtance or Impulſe from the Will, as nor being in the leaſt under its Influence; ſo that the Vibrations of the *Meninges* of the Brain, and the Dilatations of the Arteries may be ſuppoſed to be the Agents which propel the *Æther* towards the Heart.

CXXXII.

Hence then it ſeems to follow, that the alternate Contractions of the Heart may proceed from the alternate Impreſſions made on the Nerves, by the *Meninges* of the Brain, and Dilatations of the Arteries.

CXXXIII.

Upon opening the Sculls of living Animals, the *Dura Mater* may plainly be ſeen to have its *Syſtoles* and *Diaſtoles* correſponding to thoſe of the Arteries; but ſince the Heart continues to beat after the Head is cut off, or even after it is taken out of the Body, where there cannot be any alternate Succuſſions made on the Nerves by the *Meninges* of the Brain, or by the Pulſation of the Arteries, it ſeems reaſonable to believe that this Alternation is occaſion'd by ſome Impediment being given to any further Influx of the *Æther* into the muſcular Fibres of the Heart, when it is fully contracted; or otherwiſe, the Heart would conſtantly remain in a

State of Contraction, as long as there was any *ethereal Matter* flying from the Nerves.

CXXXIV.

If we conſider in how many different Directions the muſcular Fibres of the Heart run, how much they are corrugated, thickened, and ſwelled, when fully contracted, and how ſtrong and uniform the Preſſure muſt be in their greateſt Degree of Action; it may not perhaps appear unreaſonable to think that the Extremities of the Nerves, which are inſerted into every Fibre, and which are extremely ſmall and tender, may be preſſed upon and ſqueezed, ſo as to prevent the Influx of the *Æther*, till the Preſſure is abated, or till the Fibres are extended again to their uſual Lengths.

CXXXV.

What ſeems to evince the Reaſonableneſs of this Suppoſition is the Nature of the *Shaking Palſey*; where the voluntary Muſcles immediately become involuntary ones, ſo far at leaſt, as to be alternately contracted and relaxed without the Conſent or Direction of the Mind.

CXXXVI.

Now this Diſtemper we believe to proceed from a particular Weakneſs in the Nerves, whereby thoſe little Reſtrictions in them, which keep the *ethereal Matter* within due Bounds, in a State of Health, are ſo far weaken'd and deſtroyed, that the *Æther* has a Power of flying into the muſcular Fibres without any Impulſe or Direction from the Will, after the ſame manner it does into the Heart. If therefore no Interruption was to be given to the Influx of the nervous *Æther* by the Muſcles themſelves, when they were contracted, it would follow, that if the *Flexors* of any Limb were to be firſt contracted, the *Extenſors* would not be able to recover the *Æquilibrium*, and to be contracted in their Turn, without the Aſſiſtance of the Will; for if our Doctrine be right, *viz.* that muſcular Motion proceeds from the conſtituent Particles of the Fibres being drawn into cloſer Contacts by the attractive Influence of the nervous *Æther*, it neceſſarily follows, that if the ſame Quantity of *Æther* was continually to fly into a Muſcle already contracted, it would have a greater Influence on the component Particles ſo approximated, than on others in the antagoniſt Muſcles, which are diſtracted, and conſequently touch each other in fewer Points.

CXXXVII.

Hence it ſeems to be evident that ſome Impediment is given to the Influx of the nervous *Æther* when the Muſcles are contracted, or otherwiſe that they would always remain ſo; for, though the Will may be able to remove ſuch little Impediments, and to keep the voluntary Muſcles in a State of Contraction for a conſiderable Time; yet ſince the voluntary Muſcles, when affected with a Palſy, are regularly and alternately contracted, and have their

Syſtoles and *Diaſtoles* analogous to the Heart and its Auricles, I think we have good Reaſon to conclude, that the ſame Principles which contract and dilate the voluntary Muſcles, in the above-mention'd Condition, are the Principles which occaſion the *Syſtole* and *Diaſtole* of the Heart, with this Difference only, that the Influx of the Blood into the *Sinuſes* of the Heart, is what no other Muſcle in the Body has or receives; and without Doubt this may truly be reckon'd the greateſt Aſſiſtant in dilating the Ventricles of the Heart, after the attractive Influence of the nervous *Æther* ceaſes, and the *Æquilibrium* is reſtored between the ſtretched-out Fibres and thoſe which were contracted.

CXXXVIII.

What has been ſaid ſeems greatly to evince the Truth of our *third* and *laſt* Suppoſition; *viz.* that the *Diaſtole* of the Heart may depend on an Abatement of Tenſion in the contracted Fibres, a *Vis Reſtitutionis* in ſuch as are over-ſtretched, and the Influx of the Blood conjunctly.

CXXXIX.

Give me Leave to relate two or three Experiments which I have made, in order to illuſtrate the foregoing Theory, and then I ſhall conclude.

CXLI.

EXPERIMENT I.

Having obſerved that the Ventricles of the Hearts of all Animals, when bled to Death, are dilated, or ſtand wide open to a certain Size, though there happens to be very little Blood in them, it ſeems as if the *Diaſtole*, in a certain Degree, was the laſt Motion of the Heart. In order to know the Truth of this, I open'd the *Thorax* of a Dog, and kept his Lungs playing with a Pair of Bellows, that I might perfectly ſee the ſeveral Actions of the Heart and its Auricles.

CXLII.

The Auricles ſeem'd to me to begin the Motion, and the *Syſtole* of the Heart always inſtantly followed that of the Auricles. Then the *Apex* and Sides of the Heart ſunk down, and were lengthen'd of their own accord, before any Blood was thrown into the Ventricles, from the Contraction of the Auricles; for there was oftentimes more than double the Time taken up in the *Diaſtole* of the Heart, than the *Syſtole* both of the Auricles and Ventricles required.

CXLIII.

If I deſiſted from blowing freſh Air into the Lungs for ſome little Time, the Heart would lie ſtill, and yet I could recover its Motion again, by ſtrongly diſtending the Lungs. In this Action I never could diſcern that the Heart began the Motion, but the Auricles always contracted firſt, and then the Heart immediately afterwards; though, at laſt, I ſaw ſeveral Contractions of the Auricles, which were not ſucceeded by any Motion of the Heart.

CXLIV.

I muſt not forget to mention, that in another Dog I ſaw ſeveral *Syſtoles* and *Diaſtoles* of the Heart after I had purpoſely cut aſunder both the *Vena Cava's*; and could plainly perceive the Ventricles to relax and open themſelves, when very little or no Blood could poſſibly flow into them. This however is much more eaſily ſeen in the Heart of a Viper, when taken out of the Body, which will continue its *Syſtole* and *Diaſtole* for a long time; and if it ceaſes to beat ever ſo often, and you renew its Motion again and again, by breathing upon it, *&c.* You may obſerve that the Auricle always contracts before the Ventricle, and that the *Diaſtole* is the laſt Motion, though there is no Blood to diſtend the Heart.

CXLV.

The Capacity of the right Ventricle of the Dog's Heart, in the above Experiment, as it open'd of its own accord, was ſomething more than a cubic Inch, as I found, by pouring in melted Wax from a Ladle, without any Preſſure from a perpendicular

Height, after the Auricle and Blood-veſſels were cut off tranſverſely.

CXLVI.

EXPERIMENT II.

Taking the Heart out of an Ox as ſoon as I poſſibly could after he was kill'd, and having cleanſed it from the Blood, by waſhing it in warm Water, I fill'd both the Ventricles with melted Wax, without any diſtending Force more than by pouring it from the Ladle. The Heat of the Wax ſeem'd rather to contract the Fibres, and to leſſen the Capacities of the Ventricles; for ſome of the Wax kept running out from the Heart after I had done pouring it from the Ladle.

CXLVII.

The Capacity of the right Ventricle was equal to $5\frac{1}{2}$ cubic Inches. The Capacity of the left Ventricles was not quite 5 cubic Inches.

CXLVIII.

From theſe Experiments it manifeſtly appears, that the laſt or reſtitutive Motion of the Heart is to dilate or open the Ventricles, and that without any Aſſiſtance or Impulſe from the refluent Blood.

CXLIX.

Dr. *Hales* * injected the left Ventricle of the Heart of an Ox from a Column of melted Wax 4½ Feet high, which diſtended the Capacity of it to 12. 5. cubic Inches. Now ſuppoſing the Impulſe of the refluent Blood to be equal to a Column of melted Wax 4½ Feet high, and that in every *Diaſtole*, whilſt the Ox was alive, the left Ventricle was diſtended to the Capacity of 12. 5. cubic Inches, yet we may obſerve that the Heart, immediately after each *Syſtole*, relaxes and dilates its Ventricles to a certain Degree, by its own Mechaniſm, and to whatever Capacity the Ventricles are afterwards dilated, it muſt neceſſarily proceed from the Impulſe of the Blood only; all which is perfectly agreeable to our *third Query*, *viz.* that the *Diaſtole* of the Heart may depend upon an Abatement of the Tenſion in the contracted Fibres, a Motion of Reſtitution in ſuch as are over-ſtretched, and the Influx of the Blood conjunctly.

CL.

EXPERIMENT III.

I took the Heart out of a live Viper, and placing it upon a Piece of writing Paper, I found it beat at the rate of 24 or 25 Pulſations in a Minute, for three or four Minutes. After this I laid the Paper upon the Palm of my Hand, the Warmth of which increaſed the Number of Pulſes to 37 the firſt Minute, and to 48 the ſecond. Laſt of all I put it into warm Water, a Degree or two warmer than the Blood, where it beat 87 Pulſes the firſt Minute, and afterwards declined in its Motion more and more till it quite ceaſed.

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* Hæmaſtatics, *pag.* 25.

CLI.

May we not from hence obſerve what vaſt Influence *Heat* had upon the nervous *Æther* to make it fly ſo quick into the Heart as to increaſe the Pulſe to almoſt four times their uſual Number? How far the Heat in ſome ſort of Fevers may quicken the Pulſe, is not to our preſent Purpoſe to enquire.

CLII.

It is amazing to think that ſuch very ſmall Portions of the Nerves, as were cut out with the Heart in this Experiment, ſhould contain Matter ſufficient for ſo many Contractions; and that it did not all of it inſtantly fly out from the wounded Ends, even before it was put into warm Water.

CLIII.

How far theſe Experiments may ſerve to illuſtrate and confirm the Truth of our Theory of muſcular Motion, is very humbly ſubmitted to the candid

Judgment of this *Honourable* and moſt *Learned Society*; and I ſhall think myſelf well recompenſed for my Pains, if it ſo far meets with their Approbation as not to contain any thing inconſiſtent with true Philoſophy, or to any of the known Laws of the Animal Oeconomy.

FINIS.

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